

Vertical Resolution

The Cartesia system is reportedly designed to solve for altitude. The company expects test results to demonstrate vertical accuracy equivalent to the accuracy of each horizontal dimension. The company did not provide information on how this will be achieved.

Projected Cost of Deployment

Cartesia indicates that they have a very low cost design with an anticipated hardware cost of approximately \$5,000 per cell. The company reports that the only other cost item is the system processor and software located at the MTSO.

Qualcomm Incorporated

10555 Sorrento Valley Road

San Diego, CA 92121

Telephone: (619) 597-5025

Fax: (619) 587-8276

Company Background

Qualcomm Incorporated was formed in 1985. One of the company's principal business areas is the operation of the OmniTRACS system, which is the most widely used mobile communication and location system for the longhaul trucking industry. The other primary business area is the development and licensing of Code Division Multiple Access (CDMA) technology for wireless communications.

Position Determination with CDMA

Klein Gilhausen, Sr. VP of Qualcomm, wrote a white paper in approximately 1991 entitled CDMA Positioning Methods. This paper indicates that in wireless networks using Qualcomm's CDMA technology, transmissions from all cells are time synchronized using GPS satellite downlink signals to update rubidium clocks. Also, CDMA, like GPS, uses a direct sequence spread spectrum signal. The chip rates of the two systems are similar. The paper indicates that it is possible to compute position within a Qualcomm CDMA mobile phone if it is capable of receiving and tracking the pilot signals of three neighboring base stations and is provided with accurate location information of the base stations.

The "Near/Far Problem" is an issue using a CDMA network for positioning. According to Gilhausen's white paper, when a mobile unit comes close to a base station, it will become difficult to obtain an adequate signal-to-noise ratio on the neighboring base stations. The paper suggests several possible solutions to this problem including the use of one channel to support positioning or a technique using short pauses in transmission from cells to allow for timing measurements on neighboring cells. A copy of the Qualcomm white paper will be submitted to the sponsor of this study together with this report.

Status

Qualcomm reported that wireless network operators have not expressed much interest in location capability using CDMA, and, consequently, Qualcomm has not pursued development of the positioning technology beyond the analysis done in the white paper. It was indicated that Qualcomm is prepared to respond to the requirements of its customers in this area. The company reports that adding a positioning capability to CDMA would require some software work and might require a hardware change to the phone.

Accuracy

Qualcomm reports that without multipath, CDMA positioning would be accurate to within approximately 100 ft. It was stated, however, that multipath can cause a significant reduction in accuracy in a CDMA system or any other system. It was noted that Qualcomm's CDMA system can distinguish between a direct and a reflected signal path. The major problem with multipath occurs when there are no signals with a direct path.

ESL Incorporated
495 Java Drive
P.O. Box 3510
Sunnyvale, CA 94088-3510
Telephone: (408) 738-2888
Fax: (408) 743-6425

Company Background

ESL, Inc. is an operating unit of the Avionics & Surveillance Group of TRW, Inc. ESL has been active for over 25 years in designing and developing reconnaissance, surveillance, communications and imagery systems and in performing related analyses and studies. The company has some 20 years of experience in the development of radiolocation systems, primarily utilizing direction finding (DF) technology.

Positioning Technology

ESL does not have off-the-shelf capability to locate a 9-1-1 caller using a wireless phone. The company indicates that the problem of locating mobile caller is best solved through a combination of approaches which may involve the use of GPS, Interferometer Direction Finding and Time-Difference-of-Arrival (TDOA).

To locate wireless 9-1-1 callers, ESL would install a computer at the mobile telephone switching office (MTSO) which would determine the location of the mobile phone based on the responses of ESL direction finding (DF) equipment located at cellular base stations. Using Interferometer DF, the direction of arrival of the signal would be computed from the measurements of phase differences between different antennas within the DF antenna array. In addition, ESL is currently investigating the use of a low cost implementation of time-difference-of-arrival (TDOA) radiolocation to further reduce the equipment requirements at the base stations. With TDOA, instead of requiring an antenna array with up to five antennas and a dual channel receiving system, a single antenna and a single receiver would be required at each DF site, significantly reducing the cost of the system.

Status

In R&D investigations conducted between 1991 and 1993, ESL developed and demonstrated a ground-based cellular intelligence collection system. The system included a military version of ESL's portable interferometer DF device. Collected data showed DF accuracy on the order of 1.5 degrees.

ESL states that while the company does not have an off-the-shelf system for 9-1-1, based on their experience alone they believe there are enough mature technologies available in the marketplace that a practical and affordable wireless 9-1-1 system is well within reach. The challenge is to configure a low cost system.

Accuracy

ESL reports that GPS accuracy can be as good as 30 ft. (This is true assuming differential corrections are applied.) Accuracy achievable with DOA (Direction of Arrival) or TDOA technology in relatively open areas is better than 100 ft. In dense downtown areas, outdoor accuracy can degrade to 300 ft. and higher.

In-Building Penetration and Vertical Resolution

ESL indicates that if a call from a wireless phone is made within a building, neither GPS, DOA or TDOA will provide good results. With the presently available technology, the best that can be achieved is to identify the building. The company suggests that it may be necessary to install a location sensor in every base station of an in-building PCS network. If a power level sensor and coarse direction finder are used, the in-building system should be relatively inexpensive.

Cost

ESL indicates that if GPS is mandated to be included within every wireless phone sold in the U.S., the estimated unit cost would be a few dollars per phone. The cost to develop a functional trial system using DOA/TDOA is estimated by ESL at several million dollars.

Wireless Phone Location Assessment

ESL's complete report assessing the issues related to wireless phone location will be submitted to the sponsors of this study.

ArrayComm, Inc.
3255 Scott Blvd., Bldg. 4
Santa Clara, CA 95054-9082
Telephone: (408) 982-9080
Fax: (408) 982-9082

Company Background

ArrayComm, Inc. is a privately-held company which was formed in April, 1992. The company was formed to develop and license Spatial Division Multiple Access (SDMA) technology for enhanced communications quality and capacity in wireless networks. The founders of ArrayComm have extensive experience in wireless communications with companies such as Motorola and Alcatel.

IntelliCell System

The ArrayComm IntelliCell system uses SDMA technology which relies on the use of multiple element antenna arrays to locate and track users. The multi-element antenna array is used to estimate the directions of arrival of multiple signals transmitted over the same frequency (same channel) and separates the individual signals. Fundamentally, it locates sources of electromagnetic energy. ArrayComm claims to be able to resolve the angle of arrival of signals transmitted from wireless phones to fractions of a degree in clean signal environments.

The ArrayComm system is reported to be compatible with all wireless analog and digital modulation formats.

In February, 1994, ArrayComm, Inc., Watkins-Johnson Company and Spectrian, Inc. received a matching grant award from the Advanced Research Projects Agency (ARPA) as part of a \$11.4 million effort to develop "smart antenna" technology based on ArrayComm's patented SDMA technology. The matching funds will be used to develop a beta test configuration to support productizing of the ArrayComm technology.

Target Applications

ArrayComm plans to license the IntelliCell SDMA-based system to manufacturers of wireless (cellular, PCS, ESMR) base station equipment who, in turn, will sell the equipment to wireless network operators. Wireless operators using the SDMA technology will define the applications for the mobile unit tracking capability inherent in the system. ArrayComm believes that mobile 9-1-1 location estimation is possible with the company's SDMA system installed in a wireless network.

System Status

ArrayComm has developed a cell site prototype employing the SDMA technology. The company reports that it has been successfully demonstrating simultaneous communication of three cellular phones on the same frequency using its technology. To date, computing the latitude and longitude of the caller has not been a requirement. ArrayComm states that this is easy to do with the accurate angle of arrival information that is already available with their system.

The company reports that the IntelliCell system is ready to be licensed. The company is currently working to develop license agreements with wireless base station manufacturers. If successful, the system could be deployed on a widespread basis within two years.

Wireless Phone

The ArrayComm system is compatible with existing cellular phones. No modification to the phone is required for communication or positioning with the SDMA technology.

System Accuracy

ArrayComm states that its system can provide for resolution of the caller's location with a typical accuracy of approximately +/- 50 meters in rural and suburban areas. The highest accuracy is obtained when the caller is close to the base stations used in the solution.

The ArrayComm system does not resolve the floor from which a call was placed.

Dense Urban Environments

Some degradation of accuracy occurs in dense urban environments. ArrayComm claims that the system is as accurate as the size of the radiator. In urban environments, the building itself often serves as the radiator of the radio signal. In a very dense urban environment such as downtown Manhattan, it may only be possible to resolve the source of radiation to a city block. ArrayComm believes this is also true of other wireless network location technologies.

Cost

ArrayComm states that the cost for cellular operators to deploy SDMA technology will be determined by the base station manufacturers to whom the technology is licensed.

OAR Corporation
10447 Roselle Street
San Diego, CA 92121-1532
Telephone: (619) 453-4014
Fax: (619) 546-8739

Company Background

OAR Corporation was founded in 1968. The company is a developer and manufacturer of direction finding, surveillance and spectrum management products and systems. The company's emitter tracking and location devices, portable direction finders and man-portable tactical systems are sold to law enforcement agencies, military and spectrum management users in the U.S. and abroad. The company recently completed delivery on an FAA contract for radio direction finders to track planes located between radar control coverage areas. OAR teamed with Hughes STX on this project.

OAR Corporation has approximately 50 employees.

Location Technology

OAR Corporation indicates that its direction finding technology can be applied to locating callers using a wireless network. The system would include an antenna array, bearing processor and receiver installed at cell sites.

For 9-1-1 applications, the company might also incorporate signal strength measurements to help resolve the range from the base station to the caller.

System Accuracy

OAR Corporation's current direction finding technology would allow for computing the direction of the caller with an accuracy of 3 degrees RMS. In an urban environment, typical positioning accuracy would be within a city block. When positioning is based on direction finding, accuracy is greater when the caller is close to the base station.

Cost

OAR Corporation estimates that the equipment cost for an antenna, processor and receiver for installation at a cell site would be approximately \$10,000. The company believes this cost can be reduced to around \$3,000.

Scientific Research Laboratories, Inc.

P.O. Box 2729

Santa Maria, CA 93455

Telephone: (805) 928-0133

Fax: (805) 925-2744

Company Background

Scientific Research Laboratories, Inc. (SRL) was incorporated in 1983. The company produces a total of 43 product configurations including antennas (137.5 - 950 MHz), low noise amplifiers, telemetry transmitters and receivers, video transmitters and receivers, radio direction finding equipment and field survey meters.

SRL has six employees and annual sales of approximately \$1 million.

SpecTrack

Scientific Research Labs (SRL) has developed the SpecTrack system which is a channelized spectrum management system designed to identify the location of interfering emitters in the cellular and ISM bands. The base station configuration installed at the cell site includes a scanned antenna array and a chassis housing a multi-channel phase coherent receiver and processor. The system identifies the angle of arrival of any emissions from a wireless phone with an accuracy of 3-5 degrees. The SpecTrack system also includes a mobile radio direction finding unit installed in response vehicles which provides the capability to home in on the mobile phone.

Target Markets

The SpecTrack system was developed to identify the location of interfering emitters which may be jamming cellular or ISM channels. The system is also designed for site surveys to identify locations where wireless phone usage is concentrated and new cell sites may be required. SRL states that the SpecTrack technology can be effectively applied to a system for locating wireless callers for 9-1-1 response.

System Status

The SpecTrack mobile radio direction finding unit has reportedly been in successful beta test for a two year period. Beta testing of the base station unit is scheduled for the fall of 1994.

Accuracy

The SpecTrac system calculates the angle of arrival of transmissions from wireless phones with an accuracy of 3-5 degrees. The system typically resolves the location of the caller with an accuracy of 500-1,000 ft. The vehicle-mounted radio direction finder, based on input of the transmission channel, homes in on the location of the caller.

Cost

SRL reports that the estimated cost of the fixed site base station unit is \$7,500. The price of the vehicle mounted DF unit is approximately \$1,900.

SYSTEMS BASED ON EXTERNAL RADIOLOCATION NETWORKS

This section of the report covers location systems which utilize a separate network to compute the location of a 9-1-1 caller using a wireless phone. Several suppliers use an existing radiolocation network, such as the Global Positioning System (GPS) or the existing commercial FM radio infrastructure, to compute location. Other companies plan to deploy radiolocation networks with coverage in major metropolitan areas which could compute the location of mobile 9-1-1 callers and pass this information to the PSAP.

Systems developed by the following companies are covered in this sections:

- Terrapin Corporation
- NAVSYS Corporation
- Smith Advanced Technology, Inc.
- Galaxy Microsystems, Inc.
- Automatic Vehicle Monitoring Systems
 - AirTouch Teletrac
 - Pinpoint Communications, Inc.
 - MobileVision